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Weed Resistance Assessment Program (WRAP)

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The phenomena of herbicide resistance is not a new concern; triazine resistant weeds were first reported in the late 1960's. Since then, resistance has developed to many other important classes of herbicides. Although there are isolated infestations of triazine resistant weeds across Iowa, these weeds are not considered a major problem in the state. Recent shifts in herbicide use patterns has increased the potential for the development of resistant biotypes. This paper will describe factors which influence the development of resistance and how weed management programs can be manipulated to minimize the potential for resistance.

How Does Resistance Develop?

Herbicide resistance is the natural response of a weed population to selection pressure by a herbicide. Within any weed population, there is a wide variation in tolerance to herbicides. A small percentage of the population will possess a high level of tolerance, or resistance, to herbicides. If a herbicide is used repeatedly, eventually only those individuals that initially possessed resistance will remain.

Several factors influence the potential for resistance development, including: 1) the initial proportion of resistance within the population, 2) the relative fitness of resistant biotypes, 3) the size and longevity of the seed bank, and 4) the selection pressure placed on the population by the weed management program.

The first three factors describe properties related to different plant species. Differences in these properties explain why one weed species may be more likely to develop resistance than another. They also explain why resistance to different classes of herbicides develop at different rates. For example, it is believed that resistance to ALS-inhibiting herbicides occurs at a higher frequency within weed populations than the trait for triazine resistance. Therefore, ALS-inhibitor resistance appeared much more quickly than was experienced with triazine resistance.

The selection pressure placed on the weed is the final factor that influences the rate that resistance develops in a population. Factors which influence selection pressure include the effectiveness of the herbicide, the number of years a herbicide is used, and alternative control strategies used. Repeated use of a herbicide or herbicides with the same mode of action places continuous selection pressure on weeds, and may result in the development of resistant weed problems.

How can Herbicide Resistance be Managed?

The key to managing resistance is developing a weed management program that avoids placing continuous selection pressure from herbicides with similar modes of action. This can be accomplished in several ways, including tank mixes or sequential applications of herbicides with different modes of action, avoiding continuous use of herbicides with the same mode of

action, and the use of alternative control strategies, such as cultivation. Although this would seem like an easy task, it is complicated by the fact that one must consider selection pressure over several years, rather than looking at only one or two years of management.

Iowa State University is developing a software for evaluating relative risks of ALS-inhibitor resistance development (WRAP). The program is based on assigning scores to all aspects of the weed management program over a several year period. The score over a several year period provides a means of evaluating relative risks of different weed management programs. The use of ALS herbicides increases selection pressure, thus these herbicides are assigned positive scores. Non-ALS strategies (herbicides with other modes of action or cultivation) reduce the selection pressure for ALS resistance and are given negative scores. The overall score for a weed management program has little meaning by itself, but is useful when compared to scores of different management programs.

Two examples of how the program can be used are provided following this text. Table 1 illustrates how changes in the weed management program influence selection pressure on pigweed. Program 1 relies on Pursuit for broadleaf control in soybeans, but uses alternative strategies in corn. This results in low ALS selection pressure and a score of -8 for the four year period. Program 2 relies on ALS herbicides in both corn and soybeans, resulting in a positive score of 12. Program 3 is similar to Program 2 in the use of ALS herbicides, but utilizes additional strategies that reduce the selection pressure considerably. Of these three programs, Program 2 would be at the greatest risk of developing resistance in pigweed.

Table 2 illustrates the importance in considering the effectiveness of herbicides on different weed species. In this example, Program 2 from Table 1 is evaluated for selection pressure on pigweed, common ragweed, and giant foxtail. In this example, tank mixing with non-ALS herbicides greatly reduces the risk of resistance in giant foxtail, but provides little benefit when considering common ragweed or pigweed. This procedure can be used to evaluate how changes in a weed management program influence the potential for resistance development.

The software program is menu-driven using the Windows platform. The program evaluates the relative selection pressure of weed management programs on the 15 annual weed species included in I.S.U.'s Herbicide Effectiveness Ratings. In order to provide the greatest flexibility, users will be able to enter new products or modify performance ratings of herbicides. We hope to have the program ready for release in early 1995.

Table 1. Relative risk of resistance development - Redroot pigweed

Program 1.

Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Total
Strategy		Strategy		Strategy		Strategy		Strategy		Strategy		
Treflan	-3	Lasso	-1	Prowl	-3	Eradican	-3					
Pinnacle	4	Atrazine	-3	Pursuit	4	Banvel	-3					
Classic	1			cultivat	-2							
Total	2		-4		-1		-4					-7

Program 2.

Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
Strategy		Strategy		Strategy		Strategy		Strategy		Strategy	
Treflan	-3	Lasso	-1	Prowl	-3	Accent	1				
Pursuit	4	Pursuit	5	Pinnacle	4	Pinnacle	5				
				Classic	1						
Total	1		4		2		6				13

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Program 3.

Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
Strategy		Strategy		Strategy		Strategy		Strategy		Strategy	
Prowl	-3	Lasso	-1	Prowl	-3	Lasso	-1				
Pursuit	4	Pursuit	5	Pursuit	5	Pinnacle	4				
		cultivat	-3			atrazine	-3				
Total	1		1		2		0				4

Table 2. Influence of weed species on relative risk of resistance development.

Redroot pigweed

Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
Strategy		Strategy		Strategy		Strategy		Strategy		Strategy	
Treflan	-3	Lasso	-1	Prowl	-3	Accent	1				
Pursuit	4	Pursuit	5	Pinnacle	4	Pinnacle	5				
				Classic	1						
Total	1		4		2		6				

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Giant foxtail

Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
Strategy		Strategy		Strategy		Strategy		Strategy		Strategy	
Treflan	-3	Lasso	-3	Prowl	-3	Accent	4				
Pursuit	4	Pursuit	5	Pinnacle	0	Pinnacle	0				
				Classic	0						
Total	1		2		-3		4				

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Common ragweed

Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
Strategy		Strategy		Strategy		Strategy		Strategy		Strategy	
Treflan	0	Lasso	0	Prowl	0	Accent	1				
Pursuit	4	Pursuit	5	Pinnacle	0	Pinnacle	1				
				Classic	4						
Total	4		5		4		2				

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Evaluating Relative Risk of Weed Management Programs for Development of ALS Resistance

This worksheet can be used to evaluate how changes in a weed management program may influence the potential for resistance to ALS-inhibiting herbicides. Herbicides and cultivation are assigned scores according to the selection pressure they place on weeds. Weed species must be considered individually due to differences in herbicide efficacy. The assigned values represent **relative** risks; they are not intended to be used to reach a certain goal (e.g. a total of zero for a five year period).

ALS herbicides

Score	Strategy
5	Same herbicide as preceding year, G-E rating.
4	First year of use, G-E rating.
2	Same herbicide as preceding year, <G rating.
1	First year of use, <G rating.
1	Tank mix including two ALS herbicides with G-E rating on target weed. (e.g. Accent + Pinnacle on pigweed - Pinnacle would get either 4 or 5 points depending on prior history; since Accent has good activity on pigweed, it would add an additional point to the score.

Alternative Management Strategies
(4 are most negative points that can be obtained in one year)

Score	Strategy
0	Herbicide with no activity (P rating) on target weed.
-1	Herbicide with F activity on target weed.
-3	Herbicide with G-E activity on target weed.
-3	Timely cultivation.

ALS Herbicides Currently Used in Iowa Corn and Soybeans

Imidazolinones	**Sulfonylureas**
Pursuit (imazethapyr)	Classic (clorimuron)
Scepter	Pinnacle
Pursuit Plus (imazethapyr + Prowl)	Accent
Passport (imazethapyr + Treflan)	Beacon
	Canopy (clorimuron + Lexone)
	Preview (clorimuron + Lexone)